ture corresponding to the absolute temperature. The thermo-electric position of iridium among seven other metals for temperature-differences 0° and 98°·6 is thus indicated—

− Al, Sn, In, Zn, Ag, Au, Cu, Fe +

with smaller differences (0° and 5° or 10°) it comes after Au Zn. Once more, elements were constituted of indium in its chloride with zinc, copper, and iron in their chlorides, and examined. In the element indium-zinc, the indium is the positive pole; in the two others the negative. The electromotive force of In/Zn was found equal to 0·331 Daniell; of Fe/In = 0·160 D., and of Cu/In = 0·584 D.

In a paper communicated to the American Association for the Advancement of Science Dr. E. L. Nichols discusses the relation between the electric resistance of platinum and its coefficient of expansion by heat. He has made careful experiments by an ingenious method at temperatures rising up to 3000° C., and finds that all the empirical formulæ given previously by Siemens, Matthiesen, and Benoit are unreliable, and, from certain anomalies in the behaviour of the metal he concludes that it is safer to infer the temperature from its expansion than from its electric resistance.

TORNADOES, WHIRLWINDS, WATERSPOUTS, AND HAILSTORMS[1]

II.

THE *Dust Storm* of India and other dry, hot climates, is another well-marked type of the whirlwind. The observations and illustrations of these meteors, which have been made by Baddeley and others, are in a high degree instructive from the light they throw on the actual movements of the whirlwind which the dust-laden air-currents of the storm present in a visible form to the eye.

Previous to the outbreak of a dust storm, the atmosphere is unusually calm and sultry, thus essentially resembling the conditions of weather under which the tornado and whirlwind originate and which point to a vertical disturbance in the equilibrium of the atmosphere. The simplest form of the dust storm is that of a tall aërial column of sand moving onwards, and drawing into itself as it whirls round in its course, dust and other light bodies within the sweep of the strong air-currents which blow along the surface and converge vorticosely round the base of the column. A frequent form is shown in Fig. 4, which represents several dust columns grouped together, each whirling independently round its own axis with incurving air-currents at the base, whilst the group is bodily borne forward, presenting remarkably striking aspects as the forms and relative positions of the columns are changed. While engaged early in 1851 in the investigation of dust storms, Dr. Baddeley followed one on horseback, and was fortunate to note several of the important phenomena of these storms. As the dust storm passed various objects in its course, such as tents, horses, &c., it gradually diminished in size, till instead of a whirling circle of five or six feet in diameter, composed of several rotating eddies, or spirals of dust, such as are seen in Fig. 4, it terminated in a single cone, the apex of which in contact with the ground, rotated briskly from left to right, just as the whirling composite circle had done. From the cone of dust, a long ribbon-like band about a foot across, of equal dimensions throughout, extended into the atmosphere as far as the eye could see, but as its sides presented a greater opacity than the central portion it was really of a cylindrical form. This column was rendered visible by the dust it had whirled aloft, and was further observed to exhibit by the light of the sun which shone through it, a kind of vermicular spiral motion. Aloft the column extended forwards in advance of the whirling cone. Suddenly the lower portion of the column which continued to rotate to the last vanished, and the upper portion then slowly receded upwards and onwards till it passed out of sight.

The important character of the evidence adduced by the observations of dust storms towards a correct understanding of the whirlwind consists in the circumstance that it affords conclusive evidence that there is a strong inflow of the air along the surface of the ground all round vorticosely towards the base of the whirlwind, and that these same inflowing air-currents thereafter ascend through the air along the centre of the whirlwind, carrying with them the evidence of their ascent in the visible solid particles of dust, sand, and other light objects they whirl up with them in their upward course.

The most marked difference between the dust storm and the waterspout or tornado lies in the essential difference, as regards moisture, of the masses of air which are drawn into and ascend the columns of the whirlwinds. In the waterspout, certainly in all waterspouts that reach down to the surface of the earth, the earth is at, or not far from, the point of saturation, and in these cases the whirlwind is accompanied with heavy rains. In some instances the rainfall has been so excessive that it can fittingly be described as only an aërial torrent of solid water, that from the velocity with which it falls from the clouds digs

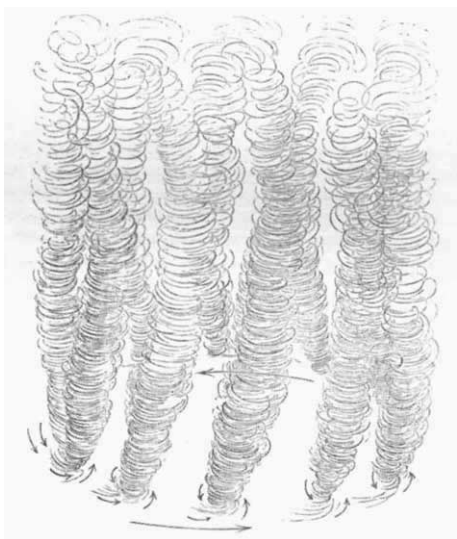

Fig. 4.

deep openings in the soil at the points where it strikes the ground. Thus immediately after the great tornado which occurred in Pennsylvania in June, 1838, Espy visited the spot and carefully examined the sides of the ridges and mountains on which its chief force was spent. He found many holes dug out by the torrents of water shot down by that tornado, which measured about thirty feet in diameter and from three to six feet deep, according to the nature of the soil and depth of the rock; the sides of the holes being in most cases cut down almost perpendicularly on their upper side, but entirely washed out on their lower side, so as to form the commencement of a ravine.

On the other hand, the air-currents which enter into and rise through the columns of the dust storm are very dry, and far removed from the point of saturation. Hence a large number of dust storms are neither accompanied nor followed by rain or any aqueous precipitation. Not a few, however, are observed to be followed towards the close of the storm with a sudden fall of rain, occasionally little more than a sprinkling, which may be due either to the condensation caused by the extreme rarefaction resulting from the rapidity of movement of the gyrations of the ascending air-currents, or to the great height in the atmosphere to which the air-currents are carried by the storm.

[1] Continued from p. 157.

Certain tracts of the ocean are known by the absence, or comparative absence, of rain, such rainless regions of the ocean being included within what may be called permanent anti-cyclones; that is, tracts of sea over which atmospheric pressure is higher than it is all round. Such regions are also remarkable for peculiarly bright clear skies and strong sunheat. Similarly the anti-cyclones which occur between, or in the immediate neighbourhood of cyclones are characterised by dry air and clear skies; and it is under such conditions that the strongest direct sun-heat is experienced. When in the warmer months of the year these anti-cyclones remain practically stationary for some time, which at that season of the year not unfrequently happens, it follows that the lowermost strata of the atmosphere become abnormally heated; thus bringing about a vertical disturbance of the equilibrium of the atmosphere, out of which whirlwinds originate. It is under these conditions, in all probability, that *white squalls*, or *fair-weather whirlwinds* occur, the originating cause of this special form of the whirlwind being the great dryness of the air due to its place in the anti-cyclone, and the abnormally rapid diminution of temperature with height owing to the strong insolation through the clear, dry atmosphere. Any cloud that may happen to be formed is at a great height. The character of the cloud, also, and the commotion and boiling of the sea which is observed immediately under it, and accompanies it as it moves onward in its course, are clear proofs that the interspace between the sea and the cloud is filled with the gyrations of the rapidly-ascending air-currents of a whirlwind, which does not appear as a water-spout simply because the air of the ascending currents is too dry or the gyrations of the whirlwind are not sufficiently rapid to bring about condensation of the vapour into visible cloud.

One of the best marked of the permanent anticyclonic regions of the globe is that large region of the Atlantic which lies to the west of Northern Africa. Over this wide tract of ocean the portion most liable to be struck by the white squall or the tornado will evidently be where the general drift of the wind issuing from the anticyclonic region is approximately antagonistic to the prevailing wind as observed at the surface. During the summer months, for example, no such antagonism exists between the winds of Florida, the southerly winds prevailing there being in accordance with the general drift of the winds for that side of the anticyclonic region of the Atlantic on the one hand, and on the other in equal accordance with the monsoonal wind of that coast towards the heated interior of the Southern United States. Quite otherwise, however, is it with the ocean off the west coast of Northern Africa. There the general drift of the winds over that part of the region overspread by the Atlantic anticyclone is north-easterly; and that this wind prevails at no very great height is abundantly shown by the quantity of African dust which falls on this part of the sea; whereas the surface wind is from the south-west, being strictly monsoonal in its character, or is an inflow towards the heated interior of North Africa. This is the region of the *Bull's-eye Squalls* of the African coast—a form of the whirlwind which deserves to be more accurately described and investigated than it has yet been, from its evident relations to the two great wind-systems referred to above, and to the very different states of atmosphere, which these imply over the restricted region where the bull's eye squalls occur.

The white squall accompanies fine weather, and is preceded immediately, and for a space of time more or less extended, by a clear sky and calm, or all but calm, weather. Its appearance is sudden, its duration brief, but its destructive power is occasionally so dreadful, that it has been known to strip a ship of every sail and mast in a few seconds, and leave it lying a helpless log amidst the tremendous seas which follow it. It is not possible, when sailing through a region overspread by the anticyclone, to make the outlook too close and sharp, particularly when the weather looks singularly fine, the skies beautifully clear, the air calm or all but calm, and *the temperature and moisture of the air noticeably high.*

On May 17, 1763, Cook saw six waterspouts on Queen Charlotte Sound, in one of which a bird was seen, and in arising was drawn in by force and turned round like a spit; an important observation, as Prof. Ferrel remarks, as showing that there is draught and an inflowing of air from all sides to supply the ascending current. In other words, the behaviour of the air-currents of a waterspout is precisely that of the air-currents of a duststorm, as actually seen in its dust-laden currents.

Another observation of great importance was made by Prof. F. E. Nipher, near Schell City, Missouri, and published in NATURE, vol. xx. p. 456, which, from its great importance in the study of whirlwinds, we here quote:—

"While making magnetic determinations at Schell City, Mo., a whirlwind of some violence passed near our tent, moving with the characteristic swaying and halting motions of the tornado. Its base was quite pointed, and about 2 feet in diameter.

"Unlike those seen last year, and described in NATURE about a year ago, there were no surface-winds strong enough to bear dust along the surface of the ground, but the dust carried up in the vortex was collected only at the vertex of the whirl. The dust-column was about 200 feet high, and perhaps 30 or 40 feet in diameter at the top. The direction of rotation was the same as that of storms in the northern hemisphere. Leaving the road the whirl passed out on the prairie, immediately filling the air with hay, which was carried up in somewhat wider spirals, the diameter of the cone thus filled with hay being about 150 feet at the top. It was then observed, also, that the dust-column was hollow. Standing nearly under it the bottom of the dust-column appeared like an annulus of dust surrounding a circular area of perfectly clear air. This area grew larger as the dust was raised higher, being about 15 or 20 feet wide when it was last observed. This whirl could be observed half a mile, finally disappearing over a hill."

Hence in this whirlwind the behaviour of the wind was exactly what is seen to obtain in the dust-storm. The light objects on the surface of the earth were lifted and carried up in whirling gyrations with a velocity so considerable that the hay and dust were driven outward by the centrifugal force of these gyrations to some distance from the axis of the whirlwind, leaving round the axis a shaft of perfectly clear air, the diameter of which gradually increased as the gyrating air-currents ascended, and friction was thereby diminished. An increase in the velocity of the ascending gyrations would, if sufficiently great to produce the required rarefaction, have filled the clear axial shaft of the whirlwind with cloudy vapour.

ELECTRICITY AT THE CRYSTAL PALACE

I.

THE work of installing the apparatus and machines at the Crystal Palace Electrical Exhibition is progressing very slowly, owing perhaps to the absence of any formal day of opening to hasten it. Before everything is fairly in its place, at least another fortnight will have elapsed, for a great deal of time is necessarily consumed in making electrical connections. Enough has been done, however, to give a fair idea of what the exhibition will be like. The official catalogue has been published in advance, and there are about five hundred exhibitors enumerated in its pages. Of these only about a hundred are from abroad, including America, so that the exhibition is rather an English than an "international" one. At the Paris International Exhibition of Electricity there were over two thousand exhibitors, and of these only one-half were French, the remainder being from every other civilised country, including Japan, which offered the first fruits of its electrical science in the shape